

VOLUME 81

PAPER No. 781

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

AUGUST, 1955



TRAVEL OF POLLUTION IN SHORELINE COASTAL WATERS

by Isadore Nusbaum, Harold E. Miller, and
Arthur W. Reinhardt, Associate Members, ASCE

SANITARY ENGINEERING
DIVISION

{Discussion open until December 1, 1955}

Copyright 1955 by the AMERICAN SOCIETY OF CIVIL ENGINEERS
Printed in the United States of America

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE \$0.50 PER COPY

THIS PAPER

--represents an effort by the Society to deliver technical data direct from the author to the reader with the greatest possible speed. To this end, it has had none of the usual editing required in more formal publication procedures.

Readers are invited to submit discussion applying to current papers. For this paper the final date on which a discussion should reach the Manager of Technical Publications appears on the front cover.

Those who are planning papers or discussions for "Proceedings" will expedite Division and Committee action measurably by first studying "Publication Procedure for Technical Papers" (Proceedings Paper No. 290). For free copies of this Paper--describing style, content, and format--address the Manager, Technical Publications, ASCE.

Reprints from this publication may be made on condition that the full title of paper, name of author, page reference, and date of publication by the Society are given.

The Society is not responsible for any statement made or opinion expressed in its publications.

This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

TRAVEL OF POLLUTION IN SHORELINE COASTAL WATERS

Isadore Nusbaum,^a Harold E. Miller,^b and
Arthur W. Reinhardt,^c Associate Members, ASCE

SYNOPSIS

Nearshore water circulation along the Pacific Ocean coast of Southern California is characterized by longshore currents within the surf zone and parallel to shore. The removal and deposition of sand on the beaches is seriously affected by these currents. Pollution discharged or brought into the surf zone will be laterally distributed along the shore affecting beneficial water uses.

An example of the effect of this nearshore water circulation on the distribution of pollution is described. The longshore currents may travel in either direction along the coast and shift from one direction to another rapidly. As a result information such as bacterial data must be carefully evaluated giving proper consideration to the water circulation pattern.

Relatively little information has been available on the distribution or travel of pollution along the shores of major bodies of water, particularly saline waters. Wastes discharged into fresh streams and systems may be considered to be distributed unidirectionally and confined within finite boundaries such as the banks of a river. Only under exceptional circumstances can a reversal of current occur. In tidal estuaries and bays one is confronted with a cyclic change in both current direction and velocity, but again the system may be considered to be bound by the shores.

Circulation patterns in the seas and oceans are much more complicated and where the dispersal of water-borne wastes is concerned, two general conditions may prevail. The discharge may be located at a depth and distance from shore where for practical purposes it may be considered that no lateral boundaries exist. Under these conditions, dispersal of the wastes would be complete and no evidence of waste could be found. The other situation is that in which the discharge is made onshore or directly offshore, or at a distance and depth from shore such that detrimental effects may result in shore waters.

A number of excellent studies have been made of nearshore water circulation, particularly in connection with beach erosion in Southern California. Shepard and Inman⁽¹⁾ have observed that there appear to be at least two interrelated current systems:

- a. Water Pollution Control Engr., San Diego Regional Water Pollution Control Board, San Diego, Calif.
- b. Executive Officer, San Diego Regional Water Pollution Control Board, San Diego, Calif.
- c. Senior San. Engr., State Dept. of Public Health, San Diego, Calif.

1) The coastal currents which flow roughly parallel to the shore, and constitute a relatively uniform drift in the deeper water adjacent to the surf zone. These currents may be tidal currents, transient wind-driven currents, or currents associated with the distribution of mass in local waters.

2) A nearshore system which may be superimposed on the inner portion of the coastal current or in the absence of a coastal current may exist independently. The nearshore system is associated with wave action in and near the breaker zone and consists of: (a) shoreward mass transport of water due to wave motion, which carries water through the breaker zone in the direction of wave propagation, (b) movement of this water parallel to the coast as longshore currents, (c) seaward return flows, such as flow along the concentrated lanes known as rip currents, and (d) longshore movement of the expanding head of the rip current.

Figure 1 is a pictorial description of the current systems. Shepard and Inman have shown that the positions of shoreward motion and seaward return are dependent on the submarine topography, the configuration of the shoreline, and the height and period of the waves. Periodicity or fluctuation of current velocity and direction is a characteristic of flow in the nearshore system.

The direction of longshore currents is primarily dependent on two factors:

1) The direction of wave propagation.

2) The rise in water level due to the shoreward mass transport of the waves, which is greatest in the zones of highest breakers along a beach. The longshore currents generally flow away from these zones of highest waves.

It has been found that water may be returned seaward by processes other than rip currents. There is a net seaward drift along the bottom inside the breaker zone and a net shoreward movement at the surface. However, there is no indication that these differential net movements between the top and bottom extend any distance outside the breaker zone, but rather that the current moves shoreward from top to bottom in one area and seaward from top to bottom in another outside of the breaker zone.

In a study of longshore currents in Southern California(2) Shepard has enumerated the characteristics of longshore currents along the coast from the U. S.-Mexico Border to Newport Beach approximately 100 miles north. There is a seasonal variation in the direction of the currents observed along the Pacific Coast. North currents for the Southern California area as a whole are most common in the late summer and fall and the southerly currents during the rest of the year. There are some individual variations from this observation. During all seasons, however, both north and south currents were found to exist at individual stations. Daily variations were observed and showed that rapid changes take place in the area. In a considerable number of cases the currents shifted from being predominantly in one direction to predominantly in another after an interval of a few days.

The bulk of the longshore currents agreed in direction with the direction in which the waves approached the shore. It was found that the velocity of the longshore currents increased with an increase in breaker height although the relationship was somewhat irregular.

The direction of the longshore currents was not related to the ebb and flood tides on the open coast. Although data was vague, there appeared some likelihood that longshore currents are increased at the time of highest and lowest tides.

Periods exist when no appreciable longshore currents are observed. These for the Southern California beaches appear to be most numerous in early winter, possibly associated with continued calms.

The velocities of the longshore currents may be quite considerable although not obvious to the casual observer. For example, on the stretch of beach to be discussed later, average velocities of north bearing currents reported by Shepard⁽²⁾ were .60 knots (1 ft/sec.) or more. Maximum currents up to 2 knots (3.4 ft/sec.) were measured.

Over 50 major and minor waste discharges into the ocean are to be found between San Francisco Bay and the Mexican Border. Of these, many terminate within the zone of influence of the longshore current systems. It is estimated that in Southern California alone the wastes of more than 6,000,000 people are discharged into Coastal saline waters.

In the southwesternmost corner of the United States and fronting along the Pacific Ocean from the Mexico - U. S. International Border north to the entrance to San Diego Bay is located one of the beaches which has been extensively studied.⁽²⁾ Into the Pacific Ocean in this area, at a point approximately 0.7 miles north of the border the combined sewage of the communities of Tijuana, Baja California, Mexico and San Ysidro, California, U. S. A. (Figure 3) is discharged.⁽³⁾ The outfall which has been designated the International Sewer terminates at approximately the extreme low tide line.

A short history of this particular international waste disposal problem would be of interest. Drainage from the communities of Tijuana and San Ysidro is into the Tia Juana River, which meanders into the United States at approximately six miles inland from the coast, and thence discharges into the Pacific Ocean at a point approximately one mile north of the Border (Figure 3). Prior to 1939, this drainage, highly contaminated by Tijuana sewage, flowed along the Tia Juana River Bed, in which were located wells which supplied domestic water for San Ysidro. Efforts made to solve the problem by the development of treatment facilities had generally ended in failure since the city of Tijuana has undergone an almost unprecedented rate of growth. From a village of 750 in 1910 the city has now attained a population of over 80,000 plus a daily tourist influx averaging 30,000 persons.

In 1935, a sewage treatment plant, consisting of two septic tanks with provisions for effluent chlorination, was built in Tijuana to accommodate the wastes of 5,000 people. This plant soon became grossly overloaded and relatively untreated sewage once more flowed in the Tia Juana River in the United States, causing a highly unsatisfactory condition.

Subsequent to 1935, the U. S. - Mexico International Boundary and Water Commission took under consideration the construction of a sewer line from the International Boundary at Tijuana to the Pacific Ocean. Following joint discussions with the California State Department of Public Health and various official and departments of San Diego County, plans and specifications for such a sewer were prepared in 1937 by the International Boundary Commission. The portion of the sewer within the United States was constructed with Federal funds by the International Boundary Commission and the section within the Republic of Mexico, by the government of Northern Lower California. The sewer was completed in 1939 and terminates 135 feet beyond the mean lower low tide line. At the lowest tides the outfall terminus is exposed.

For all practical purposes the sewage flowing through the outfall is raw and not disinfected. Over 95% of the daily sewage flow of approximately 4 mgd originates in the city of Tijuana. The sewage from San Ysidro and the U. S. Government installations near the Border passes through a comminutor and is then heavily chlorinated. This treatment has little effect on the characteristics of the total combined flow.

The beach area in the vicinity of the outfall is controlled by the U. S. Navy and is not open to the public. Starting at a point 1.9 miles north of the outfall and extending 1.1 miles north is an important San Diego County supervised and operated recreational beach known as Imperial Beach (Figure 3). It is also the western boundary of the community of Imperial Beach. A popular U. S. Navy Recreational beach is also located on Fort Emory north of Imperial Beach.

Bacteriological studies of the shore waters north of the U. S. - Mexican Border extending through the recreational area have been plagued by a high degree of uncertainty. The California State Department of Public Health has established the criteria for bathing waters that the bacterial density should not exceed 10 coliform organisms per milliliter in excess of 20 percent of the samples taken and that the bacterial data should be interpreted in conjunction with a sanitary survey of the area under study. Prior to 1950 and following the completion of the International Sewer, intermittent surveys of Imperial Beach had shown that periods existed when coliform densities were found in excess of those normal for adjacent oceanic shore waters. Actually, the coliform density in shore waters of pollution free areas has been found to be nil.

The bacteriological analyses of the samples taken during the early surveys showed a great deal of inconsistency, some samples showing high coliform densities in the surf waters to the north of the outfall and others showing virtually no coliform organisms to the north. Engineers of the International Boundary and Water Commission stated that the data was inconclusive and that evidence had not been presented which established that the beach area available to the public, that is north of the mouth of the Tia Juana River, was contaminated to a degree which made it unsatisfactory for public beach purposes and that such pollution resulted from the discharge of sewage from the International Sewer.

Surveys by the California State Department of Public Health and the San Diego County Department of Public Health subsequent to 1950 have left little doubt that the use of the public beach area north of the International Outfall has been seriously impaired. These surveys, illustrated in Figure 4 which shows the location of the sampling stations, have indicated a steadily deteriorating quality of the shore waters since 1950.

Observations of longshore currents in 1951 and 1952 made during sampling runs showed that in 19 out of 21 sets of data high coliform counts in the surf waters to the north of the outfall were accompanied by north drifting currents and low counts in the surf waters were found during periods of southerly drift.

Current observations were also made during an extensive bacteriological survey of the Imperial Beach shoreline covering May and June 1954. Samples were taken at thirteen stations from the outfall to a point four miles north. The data is summarized in Figure 5 and shows that the effects of the outfall can be traced for the full length of the sampling range. In all of the 32 sets of data high coliform counts to the north were associated with north bearing longshore currents and low counts to the north were associated with southerly currents. In addition it was observed that an outgoing or rip current existed at times between Stations 2 and 2A. At such times high counts were found up to Station 2 or 2 A and no coliform organisms were found to the north of these stations.

Sampling to the south of the outfall was limited by the proximity of the U. S. - Mexico International Boundary. The samples taken from the outfall to the south have shown that high coliform densities along this stretch are found when the north beaches are virtually free of any coliform organisms.

During 1954 it was possible to visually observe in a nearby area the longshore currents which develop. The San Diego Gas and Electric Company in constructing new power generation facilities at Carlsbad, California, 30 miles north of San Diego, had found it necessary to dredge adjacent Agua Hedionda slough. The dredgings, containing large amounts of fine suspended matter were discharged at the ocean shoreline. One could observe that in one direction from the outfall little or no excessive suspended matter appeared in the surf or ocean waters, whereas in the other direction the surf waters carried the suspended matter for long distances with little dissipation of the matter into the open ocean waters. Changes in the direction of the longshore currents were easily observable.

CONCLUSIONS

A nearshore system of water circulation exists in the ocean which is important to the distribution of pollution which may be discharged near the shore or at some point where it may reach the shore. Such pollution may travel relatively long distance with slight dissipation, thus affecting beneficial uses of the waters over a significant area.

Along the Southern California Coast the longshore currents are frequently found to flow in either direction with only slight dominance of one direction over the other. Data obtained in a series of bacteriological studies shows that the longshore current pattern should be determined before wastes are disposed of in inshore waters.

ACKNOWLEDGMENTS

The authors wish to acknowledge with appreciation the advice of Dr. D. L. Inman of the Scripps Institution of Oceanography.

REFERENCES CITED

1. "Nearshore Circulation," by F. P. Shepard and D. L. Inman, Proceedings of First Conference on Coastal Engineering, Chapter 5, 1951.
2. "Longshore Current Observations in Southern California," Tech. Memo 13, Beach Erosion Board, Corps of Engineers, 1950.
3. "Report on Effect of Sewage Discharged from International Outfall Sewer on Imperial Beach," by San Diego Regional Water Pollution Control Board, California State Department of Public Health and San Diego County Department of Public Health, 1953.

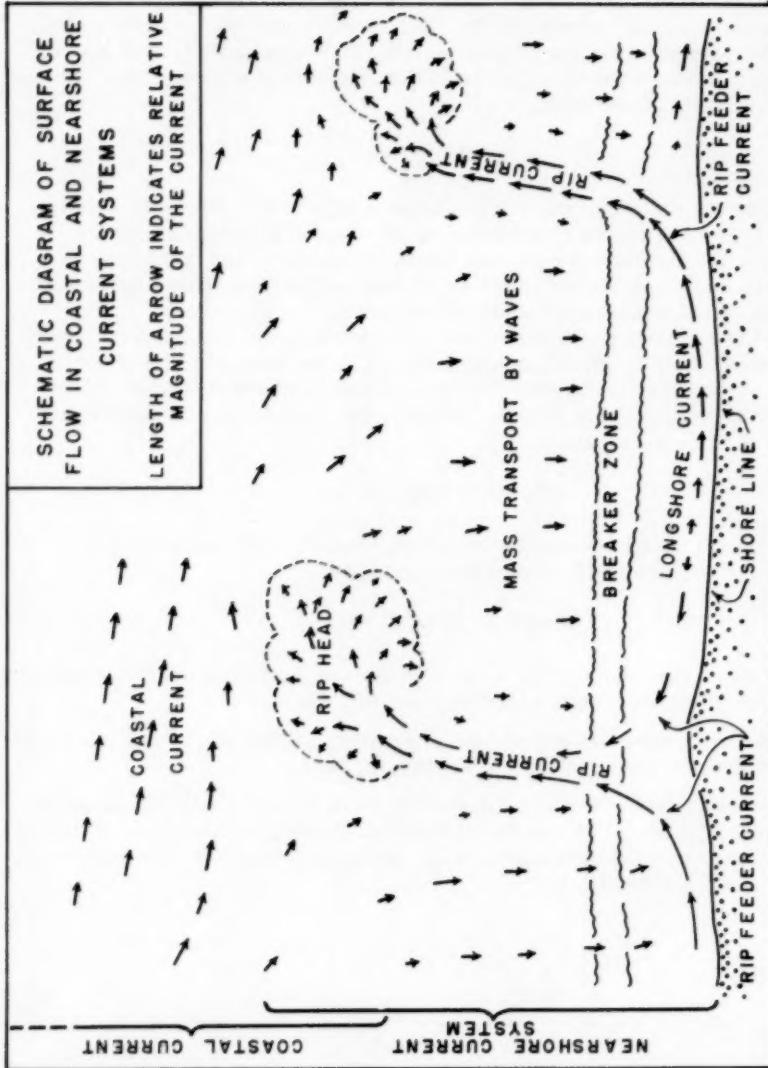
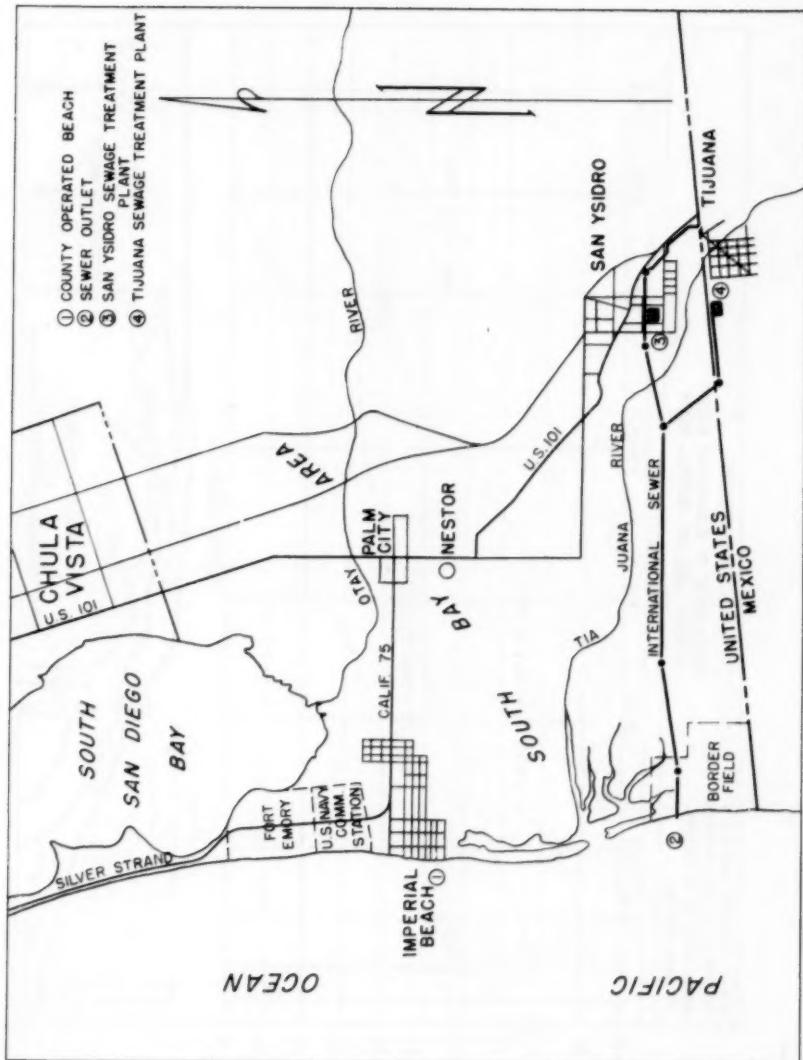


Figure 1.

(Note: There is no Fig. 2)

Figure 3.



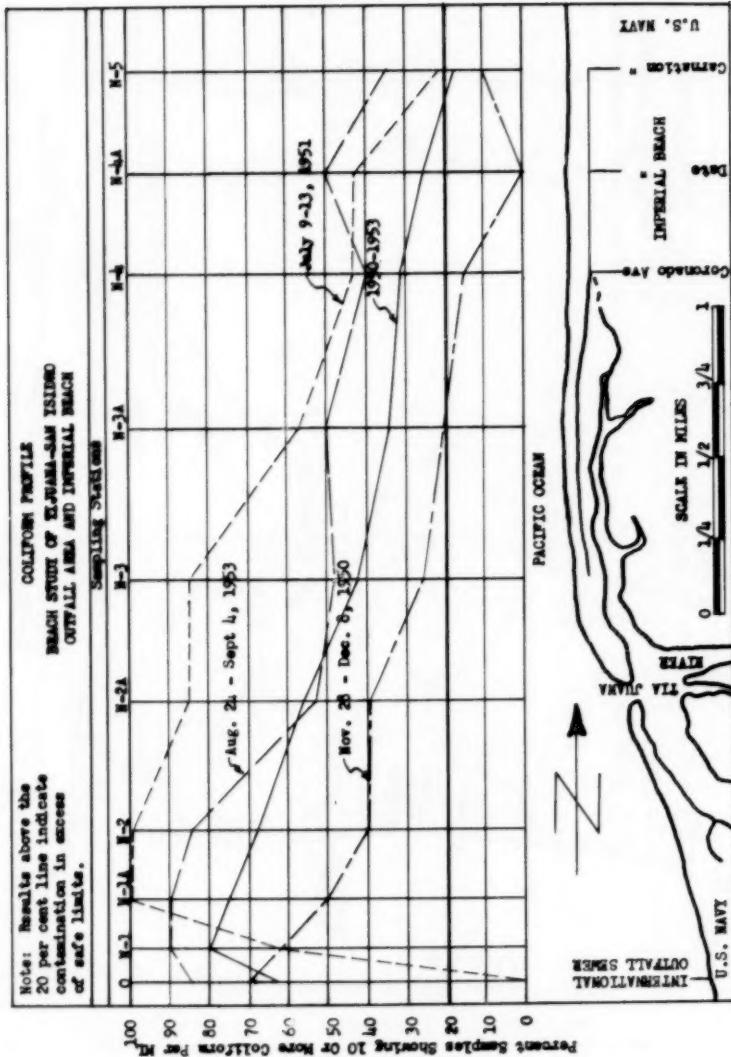


Figure 4.

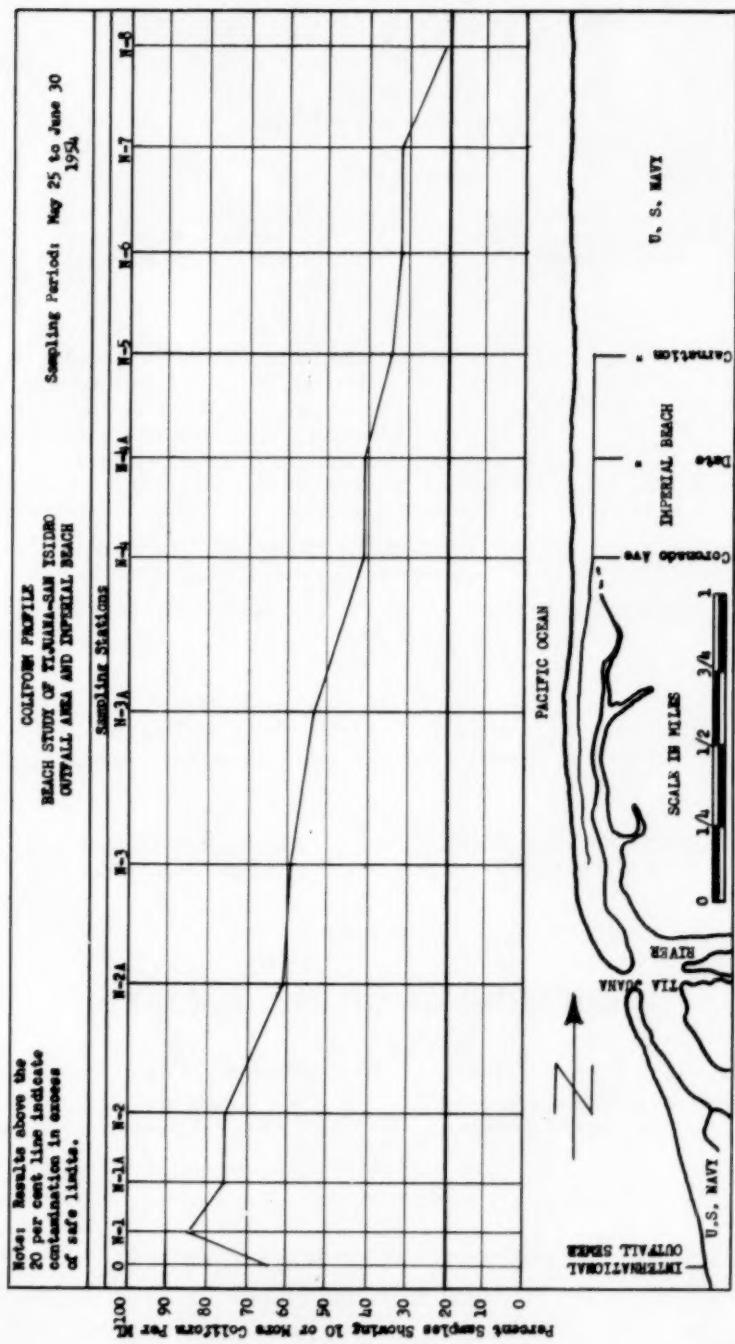


Figure 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS

OFFICERS FOR 1955

PRESIDENT

WILLIAM ROY GLIDDEN

VICE-PRESIDENTS

Term expires October, 1955:
ENOCH R. NEEDLES
MASON G. LOCKWOOD

Term expires October, 1956:
FRANK L. WEAVER
LOUIS R. HOWSON

DIRECTORS

<i>Term expires October, 1955:</i>	<i>Term expires October, 1956:</i>	<i>Term expires October, 1957:</i>
CHARLES B. MOLINEAUX	WILLIAM S. LALONDE, JR.	JEWELL M. GARRELTS
MERCEL J. SHELTON	OLIVER W. HARTWELL	FREDERICK H. PAULSON
A. A. K. BOOTH	THOMAS C. SHEDD	GEORGE S. RICHARDSON
CARL G. PAULSEN	SAMUEL B. MORRIS	DON M. CORBETT
LLOYD D. KNAPP	ERNEST W. CARLTON	GRAHAM P. WILLOUGHBY
GLENN W. HOLCOMB	RAYMOND F. DAWSON	LAWRENCE A. ELSENER
FRANCIS M. DAWSON		

PAST-PRESIDENTS *Members of the Board*

WALTER L. HUBER

DANIEL V. TERRELL

EXECUTIVE SECRETARY
WILLIAM H. WISELY

TREASURER
CHARLES E. TROUT

ASSISTANT SECRETARY
E. L. CHANDLER

ASSISTANT TREASURER
CARLTON S. PROCTOR

PROCEEDINGS OF THE SOCIETY

HAROLD T. LARSEN
Manager of Technical Publications

DEFOREST A. MATTESEN, JR.
Editor of Technical Publications

PAUL A. PARISI
Assoc. Editor of Technical Publications

COMMITTEE ON PUBLICATIONS

SAMUEL B. MORRIS, *Chairman*

JEWELL M. GARRELTS, *Vice-Chairman*

GLENN W. HOLCOMB

OLIVER W. HARTWELL

ERNEST W. CARLTON

DON M. CORBETT